SURFACE MINE WASTE AT THE GALENA SUBSITE

CHEROKEE COUNTY, KANSAS

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Introduction

Under the authority of CERCLA and SARA, the U.S. Environmental Protection Agency has been studying an area known as the Cherokee County Superfund site in southeast Kansas, an area of former lead-zinc mining. The site has been subdivided by EPA into six subsites with the largest being the Galena Subsite which surrounds the City of Galena, Kansas and encompasses about 18 square miles (Figure 1 from OUFS).

An Operable Unit Feasibility Study (OUFS) for the groundwater and surface water has recently been prepared by EPA. This OUFS develops and evaluates several potential remedial alternatives to decrease the risks to public health and the environment posed by past (1876-1960's) mining activities and the mining-related contaminants in surface mine wastes, disturbed subsurface mineralized zones, and in the shallow groundwater and surface water systems within the Galena Subsite.

Inherent in most of the remedial action alternatives evaluated by EPA is either treatment or removal and containment of the surface mine wastes. According to EPA's public health risk assessment in the OUFS, risks are present to both children and adults from ingestion of groundwater and mine wastes. In addition, EPA believes that all potential exposure pathways have a common source in the mine wastes.

After a development, screening, and evaluation process EPA has proposed an alternative which would remove and treat the surface mine wastes, thereby hopefully reducing the surface sources of metal contaminants and the subsurface formation of acid mine drainage. Surface mine wastes would be removed by excavation and then treated by milling and flotation processes to concentrate the lead and zinc sulfides (for partial cost recovery). Tailing from the treatment process would be disposed of in the mine voids. Following surface mine waste removal, the disturbed land areas would be recontoured and vegetated.

A large factor to be considered in the evaluation of the alternatives is the quantity of surface mine waste to be removed and treated as this value has a significant bearing on the costs and time involved in the remedial action.

This study was commissioned to evaluate the existing surface mine waste data and provide an additional estimate of the quantity and types of surface mine wastes in the Galena Subsite. Field work was conducted from March 27 through April 1, 1988 at the Galena Subsite with literature review and calculations occurring before and after the field work.

Surface Mine Waste Types

As defined by EPA, mine wastes is a collective term that includes bullrock, dump material, chat, slag, and tailing all derived from mining and smelter activities. In this study bullrock and dump material were combined into one category as waste rock. In addition, two additional waste types were identified and categorized, overburden and stream sediments.

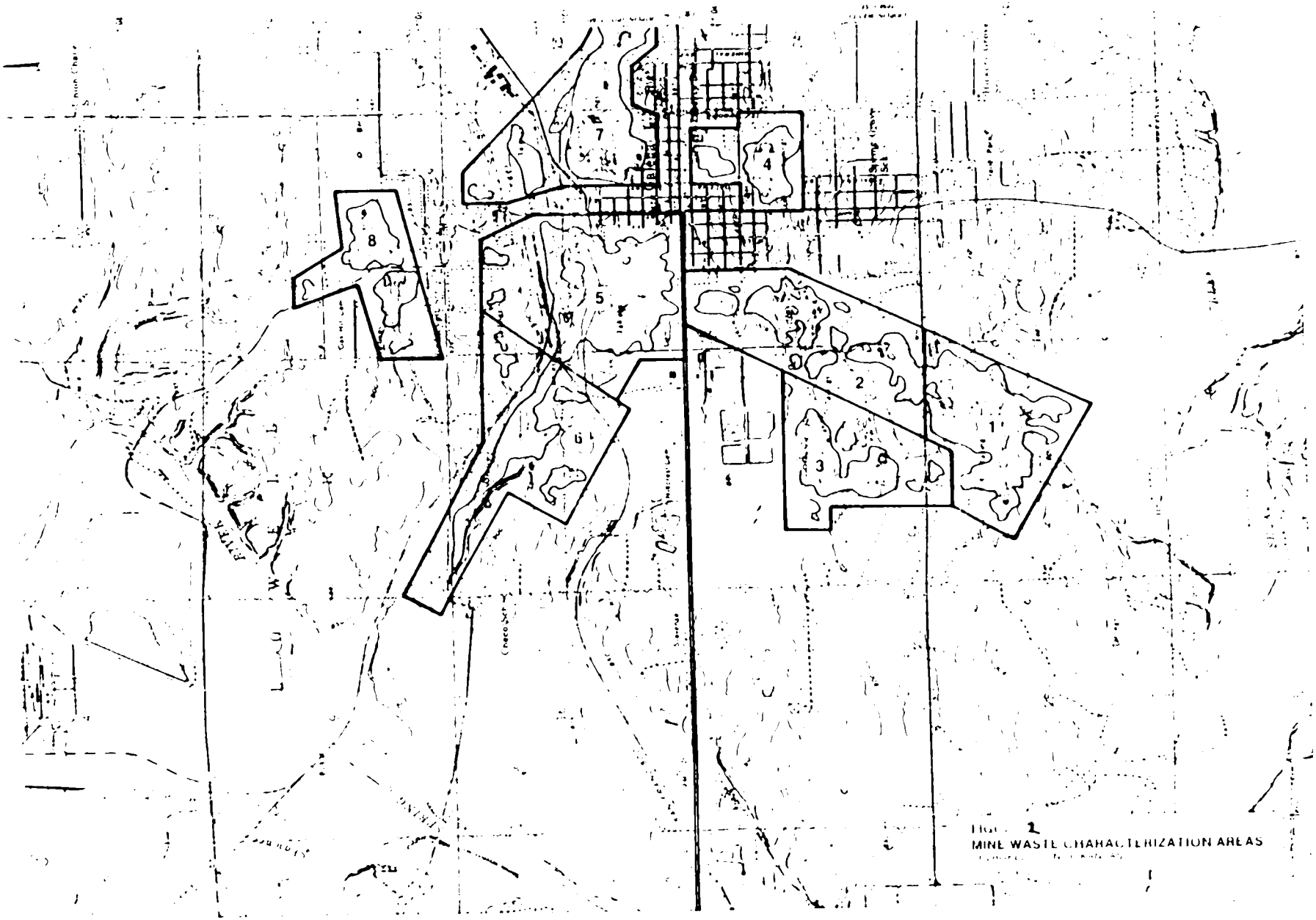
Bullrock is very coarse material and boulders removed in shaft excavation. Dump material is subeconomic ore from minus 1/4 inch to boulder size excavated from the subsurface workings and deposited on the surface in the process of mining. It is commonly mixed with the bullrock. Overburden is similar to dump material in that it is derived from removing the surface rocks over a shallow orebody and usually deposited next to the mine opening. All three of the above categories are usually mixed on the surface. Chat is a fine grained material, mostly chips of host rock, that has been milled to remove the sulfides. It is easily distinguished from the other waste materials by its smaller grain size and gray color. Stream sediments are materials found in the area streambeds from the erosional process on any of the above materials and may consist of a mixture of the other waste types, although usually smaller sized in nature.

Procedures

In addition to the maps and detailed data presented in the OUFS, black and white aerial photos taken in 1978 were obtained from the Soil Conservation Service. These photos were used in the field to outline and characterize the surface mine waste areas in the eight zones established by EPA for their analysis (Figure 2 from the OUFS) according to the five waste types previously described.

Areal extent of each waste type was estimated by actually walking each zone and outlining areas on the aerial photos in the field. Visible known locations and reference points such as streets or roads, ponds, buildings, powerlines, and streams were used to locate positions in the surface waste fields. Pacing of areas and piles was utilized as much as possible.

For individual piles an estimate of height was made by either assuming a total height in the case of a cone shaped pile or an average height in the case of an irregular shaped pile. Circumference of each pile was measured by pacing the surface contour of the pile base. Note was taken as to the location of any numbered and flagged survey stakes placed by EPA in their sampling program and heignt, width, length or circumference estimated for any piles so marked.



MINE WASTE CHARACTERIZATION AREAS

Larger areas of mine waste were walked and an estimate of average waste depth over the area made. Where minimal piles existed in an area or the area had some natural surface showing, the depth was usually estimated at three inches. Areas with larger piles or minimal natural surface were estimated at six inches depth. A shovel was utilized to dig shallow holes to determine natural surface levels. In addition, ravines and washouts, as well as mine shafts and pits, were utilized to ascertain the natural surface levels. Slope of the natural topography was also taken into account when estimating pile or area waste depths. Areas with larger heaped piles and/or spreadout zones were usually estimated at one foot in depth. Some areas mapped contained essentially one pile whose dimensions were estimated as described in the previous paragraph. Depth estimates also attempted to include the surface and mine shaft depressions which contained considerable mine waste in the slumped or cone shapes.

Areas on the marked up aerial photographs were determined by planimeter by Allgeier, Martin & Associates of Joplin, Missouri to obtain acreage figures for each mine waste area identified in the photographs.

Volumes for each area or pile were calculated using standard geometric formulas for cones, wedges, cubes, or cylinders from the dimensions estimated or measured in the field. Total zone volumes were then calculated by summing the previously calculated volumes of each waste type and subzone.

Interpretation of Results

Appendix A contains the marked up aerial photographs utilized to determine the areal extent of the various types of mine wastes. Appendix B contains the results of the planimetering of the areas. Table 1 presents a summary of the acreage of surface mine wastes by zone. Approximately 710 acres of surface mine wastes were identified in the eight zones delineated by EPA. A 1983 study by McCauley of mine and mill waste and disturbed areas in the Galena area yielded an estimate of 891 acres. This figure has been used by EPA directly in its cost estimate for reclamation. A comparison of McCauley's areas shown in Figure 3 and EPA's areas shown in Figure 4 with the Appendix A aerial photographs shows a general agreement regarding delineation of surface mine waste areas. The difference in estimated acreages probably is a function of the definition of waste coverage and the fact that some of McCauley's areas are outside the eight zones established by EPA. In particular, in Section 27 of Figure 3, some of the area shown as disturbed is actually natural ground surface. In addition, it is likely that some of the surface mine waste has been removed (chat for roadways and fill, for example) or disturbed areas reclaimed for other uses (such as areas 29 and 20 on Figure 3). In any case the

Table 1

Areas of Mine Waste

Area	Acres	Percent of Total
Zone 1	109.94	15.5
Zone 2	97.96	13.8
Zone 3	95.03	13.4
Zone 4	29.25	4.1
Zone 5	145.98	20.6
Zone 6	47.48	6.7
Zone 7	133.34	18.8
Zone 8	50.80	7.2
Total	709.78 acres	
	3,435,335 yd^2	
	30,918,017 ft^2	

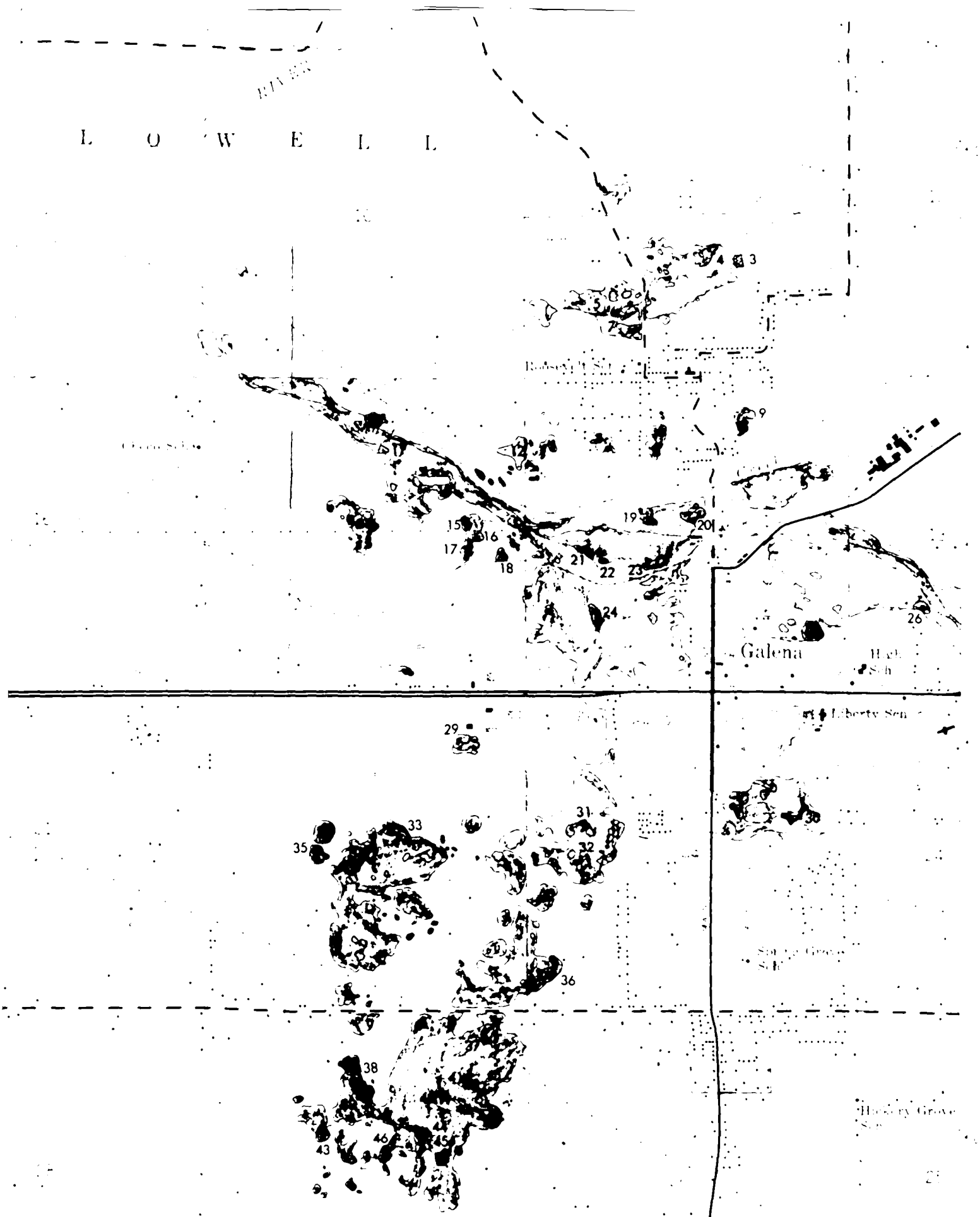


Figure 3

Disturbed Areas (from McCauley)

Blue - Waste pile
Orange - Area of General Mine Waste Disturbar

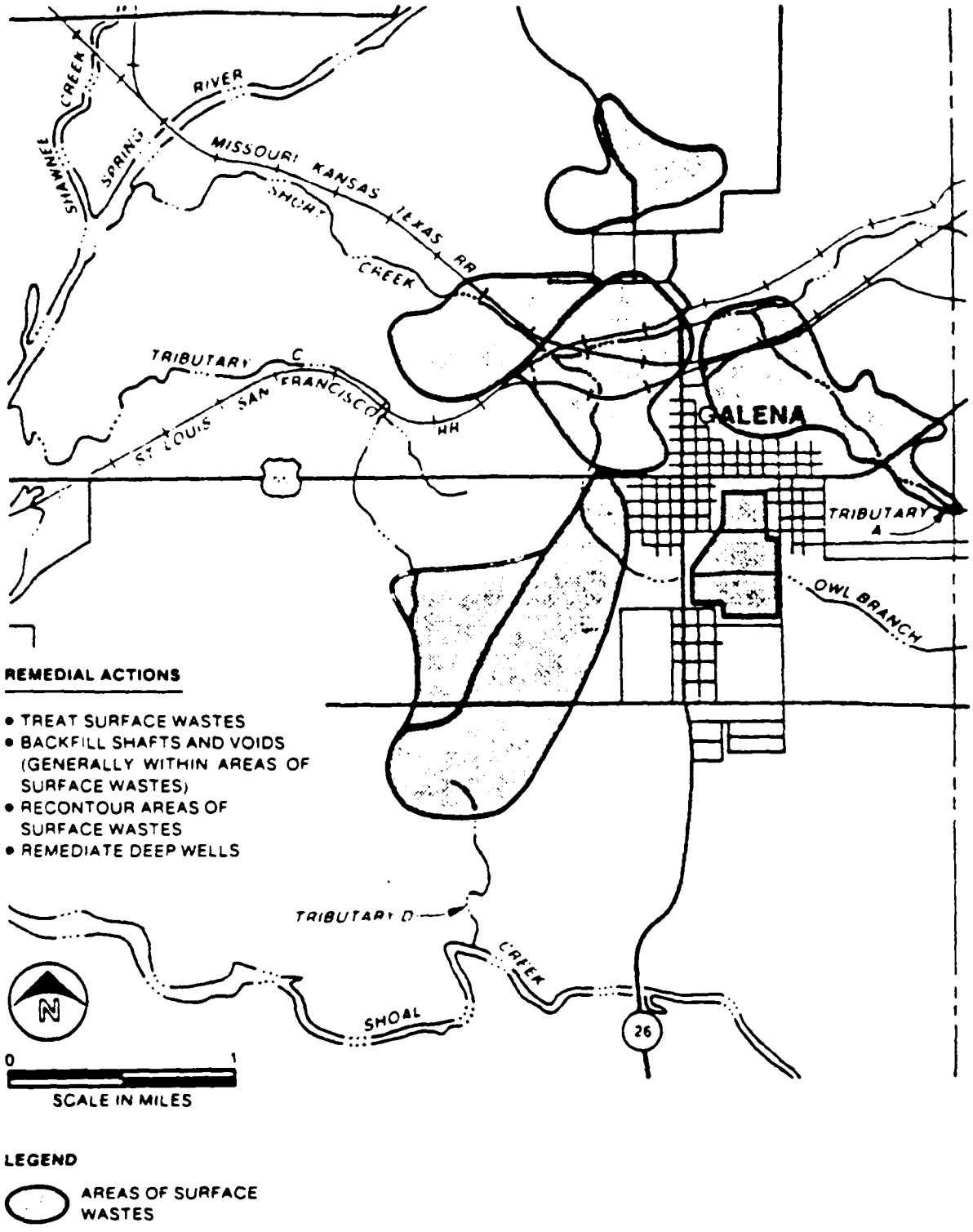


Figure 4

Areas of Surface Wastes
(from EPA OUFS Figure 6-2)

FIGURE 6-2
ALTERNATIVE 2
REMOVE AND TREAT SURFACE WASTES, BACKFILL SHAFTS AND VOIDS
CHEROKEE CO KANSAS
GALENA SUBSITE—OUFS
GROUNDWATER/SURFACE WATER

710 acre estimate is most likely on the low side and it is probable that at least that amount would require reclamation if EPA's remedial alternative were implemented.

Appendix C contains the volumetric calculations for each waste area delineated on the aerial photographs. Table 2 presents a summary of the estimated volumes of surface mine waste by zone. Approximately 1,279,000 cubic yards of surface mine waste were estimated to exist within the eight zones delineated by EPA. This is nearly 4.5 times the 283,000 cubic yards estimated by EPA (shown in Table 3) in the OUFS.

Appendix D contains the EPA detailed waste volume calculations. Although twenty sample points (piles) were taken in each zone by EPA, the vast majority of the volume calculated by EPA for each area was not sampled and it is unertain how these volumes were estimated. A reverse calculation assuming the 283,000 cubic yards in an area of 891 acres yields an average depth of mine waste of only 2.36 inches, which from visual observation of the areas seems a gross underestimate. However, at 1,279,000 cubic yards in an area of 710 acres the average depth of mine waste would be 13.40 inches which seems more logical.

During the field work 54 out of the 160 EPA sampling point stakes were located, although an attempt to locate all stakes was not undertaken. All stakes located were on piles of bullrock, dump material, or overburden while none were observed on chat piles. As an additional exercise to compare individual pile volumes, these staked piles were measured in the field. Appendix E presents the comparison of volumetric data for these 54 piles. In essence the field measurements show an increase in pile volume of 370% over that estimated by EPA in Appendix D. This correlates fairly well with the 450% increase in the overall area volume of mine waste. The Appendix D data appears to have utilized standard pile cones with dimensions of 9 feet high and 31 feet in diameter or multiples of those dimensions. In reality, the piles are not nearly that standard or regular in shape.

In 1983 McCauley also estimated the size of a number of "chat" piles in the Galena area. His measurements were only of individual large piles and in reality did include some rock piles in addition to chat. If one assumes a standard cone shape for most and either a wedge or cube shape for the others, the range of volumes for 16 piles alone is from 293,000 to 392,000 cubic yards as shown in Table 4. Either of these values is greater than the EPA estimate for the whole area.

A further attempt to correlate volumes estimated in this study with McCauley's estimates yielded Table 5. This data indicates that, if anything, the estimates from this study may even be on the low side.

Table 2

Volume of Mine Waste

Area	Cubic Yards	Percent of Total
Zone 1	161,156	12.6
Zone 2	113,119	8.8
Zone 3	90,652	7.1
Zone 4	56,318	4.4
Zone 5	306,821	24.0
Zone 6	81,703	6.4
Zone 7	377,791	29.5
Zone 8	91,495	7.2
Total	1,279,055 yd^3	
	34,534,485 ft^3	

Table 3

EPA Mine Waste Volume Summary

Zone	Volume Cubic Yards	Percent of Total
1	45,254	16.0
2	40,490	14.3
3	25,328	9.0
4	13,542	4.8
5	24,907	8.8
6	32,938	11.7
7	86,982	30.8
8	13,068	4.6
	282,509	100.0

Table 4

Estimates of Pile Volumes

McCauley Number	McCauley Measurements	Assumed Shape	Volume (yd^3)
5	12.5' H x 400' dia.	Cone	19,400
8	25' H x 150' dia.	Cone	5,456
10	40' H x 300' dia.	Cone	34,920
12	300' W x 450' L x 20' H	Wedge-Cube	50,000-100,000
14	20' H x 100' dia.	Cone	1,940
15	30' H x 180' dia.	Cone	9,428
18	150' W x 240' L x 30' H	Wedge-Cube	20,000-40,000
24	120' W x 300' L x 20' H	Wedge-Cube	13,333-26,667
25	75' H x 300' dia.	Cone	65,475
27	12.5' H x 250' dia.	Cone	7,578
28	125' W x 270' L x 12.5' H	Wedge-Cube	7,813-15,625
31	100' W x 200' L x 20' H	Wedge-Cube	7,408-14,815
34	25' H x 350' dia.	Cone	29,706
44	25' H x 220' dia.	Cone	11,737
45	12.5' H x 200' dia.	Cone	4,850
46	20' H x 150' dia.	Cone	4,365
	Total (range)		293,409-391,962

Table 5

Comparison of Volumes of Mine Waste

McCauley Number	Andes Number	Volume (yd^3) McCauley 1983	Volume (yd^3) Andes 1988
44	1H-C7	11,737	3,468
45	1H-C8	4,850	6,291
31	2D-C5	7,408-14,815	7,113
34	3C-C5	29,706	13,227
25	7B-C2	65,475	75,972
10	6D-C1	34,920	33,880
18	5ZA-C1	20,000-40,000	25,937
12	5D-C1	50,000-100,000	39,115
14	6A-C2	1,940	3,323
5	8A-C3	19,400	18,969
	Totals	245,436-322,843	227,295

Although the OUFS did not attempt a breakdown of volumes or acreages by waste type, this study allowed such an evaluation. Table 6 presents a breakdown by type of surface mine waste observed. Although over 58% of the surface waste is chat, the waste rock estimate is still over 1.7 times the EPA estimate for the whole area.

Conclusions

Data and estimates of surface mine waste in the Galena Subsite generated by this study indicate that the waste volumes given by EPA in the OUFS have been grossly underestimated. Approximately 710 acres of mine waste area were mapped containing an estimated 1,279,000 cubic yards of surface mine waste. This represents an increase of around 450% more than presented in the OUFS. Such an additional amount would increase the operating time for any milling operation to around nine years with an attendant increase in operating and tailing disposal costs.

Correlation of the findings from this study with those from McCauley's 1983 survey indicated a general agreement in affected acreages and substantiated that estimated waste volumes may actually be on the low wide. McCauley's data further indicates the underestimation by EPA of the surface mine waste volume.

Based on this significant increase in surface mine waste volume, and thereby treatment costs, reevaluation of the remedial action alternatives by EPA would appear to be in order.

Table 6

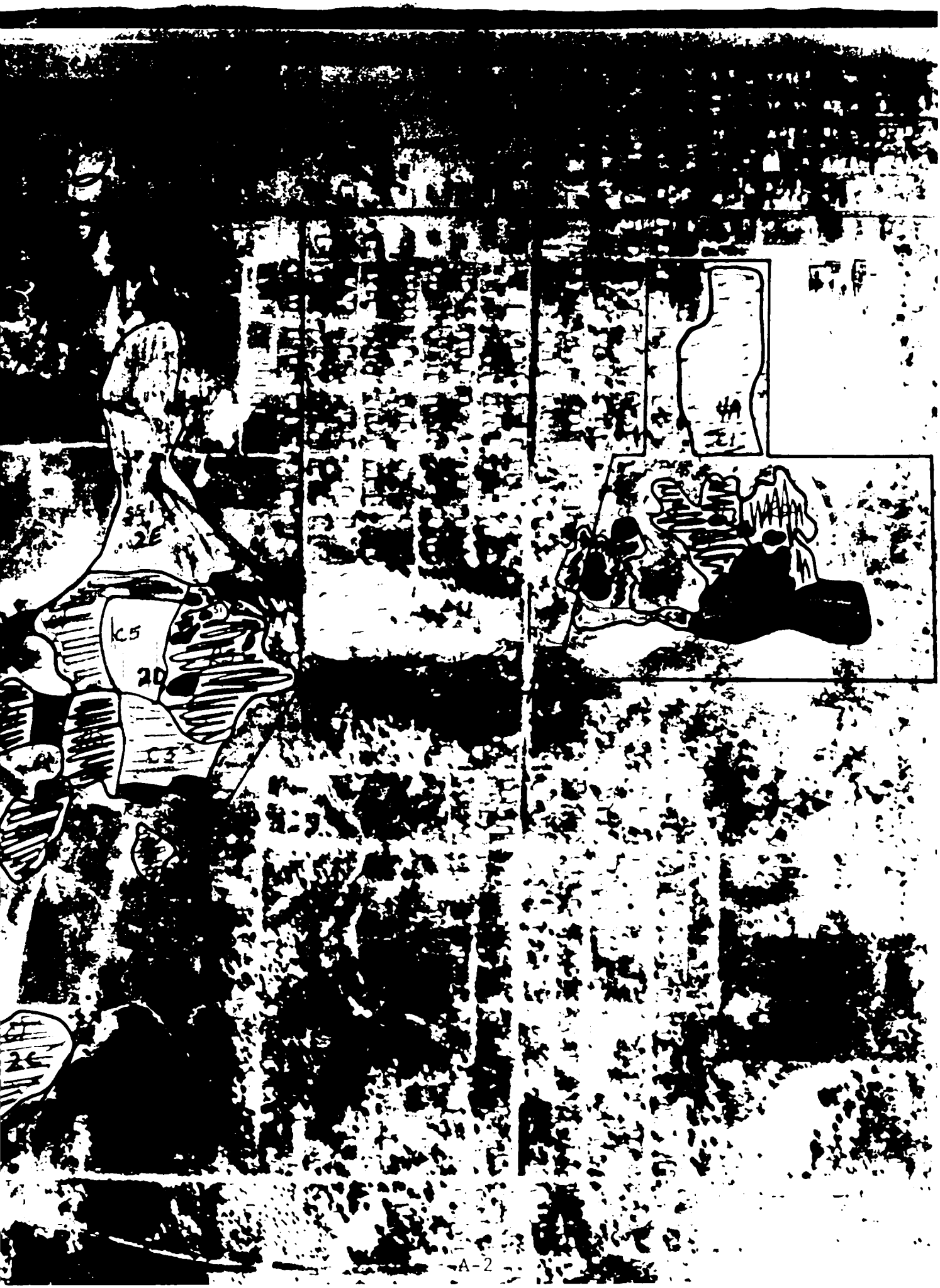
Mine Waste Types

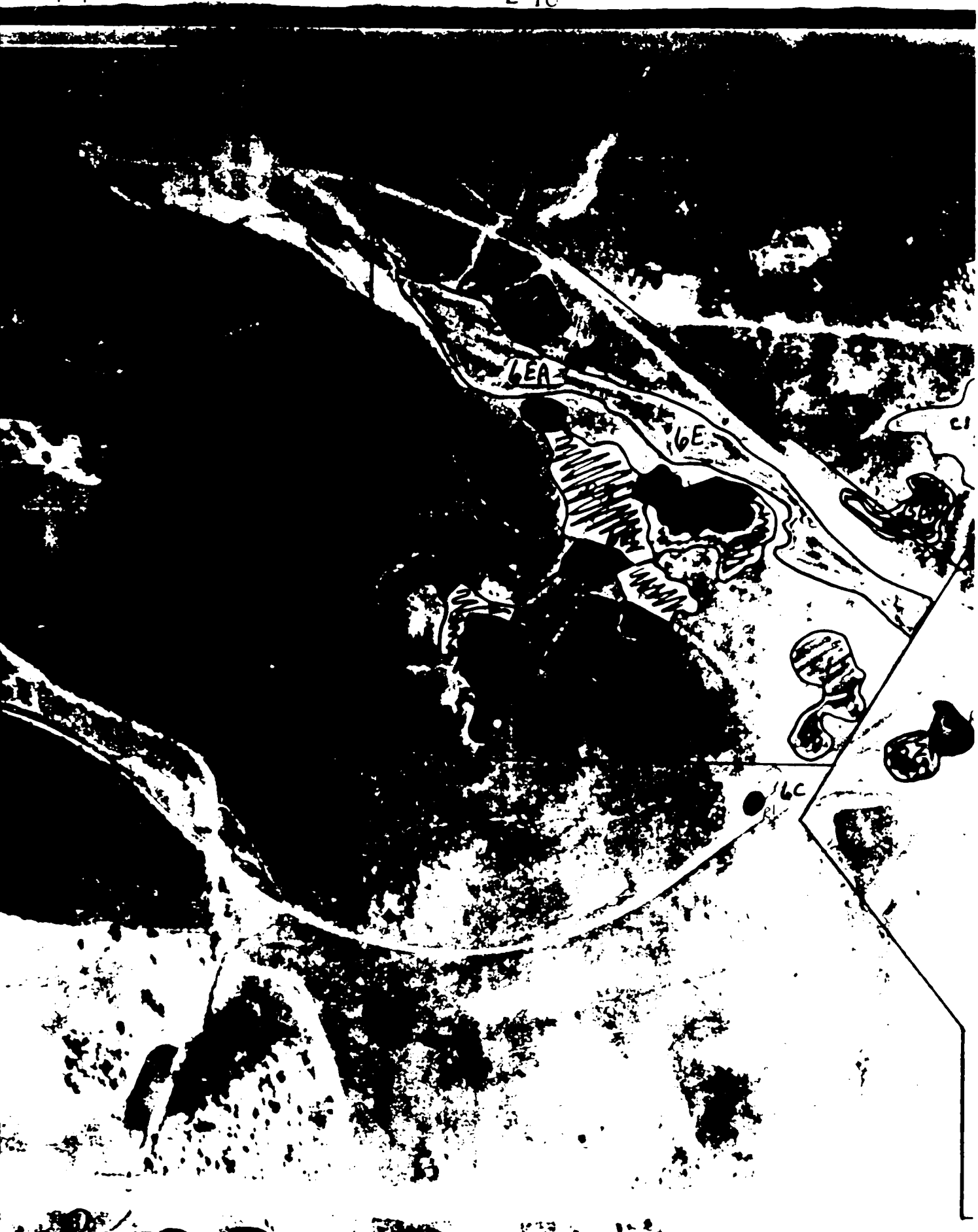
	Acres	Cubic Yards	%
Waste Rock	317.58	488,696	38
Chat	311.79	735,639	58
Overburden	2.46	19,840	2
Stream Sediments	60.12	34,396	3
Slag	.21	484	<1

APPENDIX A


R1
R3


LCS
S
M2A
C2R1
C3
C4
2B
SSI


2E
LC5
2D
LC3
2F
2I


16A
16E
C1
16C

3-23 L


STA
B-3
SS1
3 L


T-29
T-46
C3
L6
L4

APPENDIX B

AREAS DETERMINED BY PLANIMETER

Area 1A	R1	3.94			
	C1	.68			
	C2	1.18			
Area 1B	R1	.49			
Area 1C	C1	.77			
Area 1D	R1	1.60			
	C1	1.34			
Area 1E	R1	.75			
Area 1F	R1	.49			
Area 1G	R1	.34			
Area 1H					
Unmarked		.65			
	R1	5.95		C1	1.40
	R2	.30		C2	1.16
	R3	.46		C3	3.60
	R4	1.18		C4	.34
	R5	.35		C5	2.90
	R6	2.57		C6	.20
	R7	1.91		C7	4.30
	R8	10.34	minus C6	C8	3.90
	R9	5.50		C9	1.59
	R10	.96		C10	9.23
	R11	1.03		C11	5.37
		Pond	.12		
	R12	.40		C12	4.42
	R13	4.71		C13	3.53
	R14	9.21	minus C15	C14	.91
				C15	.27
	SS1	3.18		C16	.45
	SS2	7.21			
Area 2A	C1	5.99		R2	.88
		Pond	.16	Ponds (inside area)	
	C2/R1	1.76			
		Pond	.25		
	C3	4.29			
Area 2B	R1	15.98		C1	1.17
	R2	5.33		C2	1.01
				C3	.90
	SS1	1.75		C4	2.51
		Pond	.11 (inside area)		

Area 2C	C1	5.53			
Area 2D	R1	2.05		C1	3.46
	R2	3.71		C2	.96
				Pond	.23
	R3	.44		C3	4.32
	R4	.44		C4	5.37
	R5	9.02		C5	4.41
		Pond	.14		
		Pond	.23		
		Pond	.10		
		Pond	.43		
	S1	.08			
Area 2DA	C1	.91			
Area 2E	SS1	14.36			
Area 2F	C1	1.10			
Area 3A	C1	2.39			
Area 3B	R1	2.94			
Area 3C	R1	3.12		C1	1.95
	R2	3.92		C2	3.66
				Pond	.20
	R3	16.10		C3	8.70
				Pond	.12
	R4	.66		C4	2.27
				Pond	.37
	R5	16.07		C5	8.20
		minus C12			
		Pond	.10		
	R6	7.40		C6	.98
				C7	2.20
Ponds (inside area)				C8	6.69
				C9	5.18
				C10	.39
				C11	2.81
				C12	.35
Area 4	R1	1.10		C1	.12
		Pond	1.50		
	R2	3.30		C2	2.97
		Pond	.22		
	R3	3.28		C3	2.26
		Pond	.23		
	R4	4.37		C4	.27
		Pond between R2 & R4	.16	C5	.37
	SS1	1.33			

Area 4A	C1	8.59			
Area 5D	C1	4.85			
Area 5DA	R1	2.69			
Area 5ZA	R1	.76			
	C1	1.34			
Area 6A	R1	.66		C1	.14
	R2	1.97		C2	2.06
	R3	1.75		C3	.73
	R4	1.36		C4	.19
	R5	1.41			
	R6	1.20		Pond	1.69
	R7	5.71			
	R8	1.93			
	R9	2.78			
Area 6B	C1	3.75			
Area 6C	R1	.23			
Area 6D	C1	2.10			
Area 6E	SS1	16.67			
Area 6EA	R1	.15			
Area 7A	R1	.75		C1	1.81
	R2	2.63		C2	7.19
	R3	13.85		C3	.56
	R4	2.84		C4	1.22
	R5	4.84		C5	2.78
	R6	.97			
	R7	2.03		SS1	3.01
	R8	.89		SS2	.68
	R9	5.34			
Pond (inside area)			1.33		
Area 7B	R1	4.90		C1	3.48
	R2	1.18		C2	3.14
	R3	.88		C3	7.39
	R4	3.37		C4	2.68
	R5	24.00		C5	1.70
	R6	7.21			
	SS1	3.15			
Pond (inside area)			1.83		
Area 7C	C1	15.71			

Area 8A	R1	.78		C1	.33
	R2	.40		C2	1.25
	R3	.53		C3	5.88
	R4	.20		C4	2.48
	R5	.49		C5	.01
				C6	3.68
	S1	.13			
				OB1	1.85
				OB2	.61
Ponds (inside area)			.25		
			.44		
Area 8B	R1	15.68		C1	7.03
		Pond	.48		
	R2	1.68		C2	3.61
	R3	3.18		C3	.31
		Pond	.49		
Ponds (inside area)					

APPENDIX C

VOLUME CALCULATIONS

Zone Designation		Acres	Height (ft)	Volume (yd^3)
1B	R1	.49	1.0	790
1C	C1	.77	5.0	6,210
1D	C1	1.34	0.5	1,081
	R1	1.60	0.5	1,290
Subtotal		2.94		2,371
1E	R1	.75	0.5	605
1F	R1	.49	0.5	395
1G	R1	.34	0.5	274
1H	C1	1.40	3.0	6,775
	C2	1.16	1.0	1,871
	C3	3.60	2.0	11,614
	C4	.34	3.0	1,645
	C5	2.90	0.5	2,339
	C6	.20	3.0	968
	C7	4.30	0.5	3,468
	C8	3.90	1.0	6,291
	C9	1.59	1.0	2,565
	C10	9.23	1.5	22,332
	C11	5.37	1.0	8,662
	C12	4.42	0.5	3,565
	C13	3.53	0.5	2,847
	C14	.91	0.5	734
	C15	.27	1.0	436
	C16	.45	5.0	3,629
	R1	5.95	1.0	9,597
	R2	.30	2.0	968
	R3	.46	5.0	3,710
	R4	1.18	0.5	952
	R5	.35	0.5	282
	R6	2.57	0.5	2,073
	R7	1.91	.25	770
	R8	10.14	0.5	8,178
	R9	5.50	1.0	8,872
	R10	.96	2.0	3,097
	R11	.91	2.0	2,936
	R12	.40	2.0	1,290
	R13	4.71	0.5	3,799
	R14	8.94	.25	3,605
	SS1	3.18	.25	1,282
	SS2	7.21	.25	2,907
	Pond	.12	-	-
Subtotal		98.36		134,059

Zone Designation		Acres	Height (ft)	Volume (yd^3)
2C	C1	5.53	1.0	8,920
2D	C1	3.46	1.0	5,581
	C2	.96	1.0	1,548
	C3	4.32	1.0	6,968
	C4	5.37	.25	2,165
	C5	4.41	1.0	7,113
	R1	2.05	0.5	1,653
	R2	3.71	1.0	5,984
	R3	.44	0.5	355
	R4	.44	0.5	355
	R5	8.12	1.5	19,646
	S1	.08	0.5	65
	Ponds	1.13	-	-
Subtotal		34.49		51,433
2DA	C1	.91	.25	367
2E	SS1	14.36	.25	5,791
2F	C1	1.10	1.0	1,774
1A	C1	.68	4.0	4,387
	C2	1.18	3.0	5,710
	R1	3.94	1.0	6,355
Subtotal		5.80		16,452
2A	C1	5.83	.25	2,351
	C2/R1	1.51	1.0	2,436
	C3	4.29	0.5	3,460
	R2	.88	1.0	1,419
	Ponds	.41	-	-
Subtotal		12.92		9,666
2B	C1	1.17	.25	472
	C2	1.01	1.0	1,629
	C3	.90	1.0	1,452
	C4	2.51	.25	1,012
	R1	15.87	1.0	25,598
	R2	5.33	0.5	4,299
	SS1	1.75	.25	706
	Pond	.11	-	-
Subtotal		28.65		35,168
3A	C1	2.39	0.5	1,927
3B	R1	2.94	0.5	2,371

Zone Designation		Acres	Height (ft)	Volume (yd^3)
3C	C1	1.95	.25	786
	C2	3.46	0.5	2,790
	C3	8.58	1.5	20,759
	C4	1.90	0.5	1,532
	C5	8.20	1.0	13,227
	C6	.98	0.5	790
	C7	2.20	0.5	1,774
	C8	6.69	1.0	10,791
	C9	5.18	.25	2,089
	C10	.39	0.5	315
	C11	2.81	0.5	2,266
	C12	.35	0.5	282
	R1	3.12	1.0	5,032
	R2	3.32	1.0	5,355
	R3	16.10	0.5	12,985
	R4	.66	1.5	1,597
	R5	15.62	0.5	12,598
	R6	7.40	0.5	5,968
	Ponds	.79	-	-
Subtotal		89.70		86,354
4	C1	.12	3.0	581
	C2	2.97	0.5	2,395
	C3	2.26	1.0	3,645
	C4	.27	2.0	871
	C5	.37	10.0	5,968
	R1	1.10	8.0	14,194
	R2	3.08	1.0	4,968
	R3	2.68	2.0	8,646
	R4	4.37	1.0	7,049
	SS1	1.33	0.5	1,073
	Ponds	2.11	-	-
Subtotal		20.66		49,390
4A	C1	8.59	0.5	6,928
5B	C1	.57	2.0	1,839
	R1	2.02	1.0	3,258
Subtotal		2.59		5,097
5C	R1	2.65	0.5	2,137
5E	R1	1.08	1.0	1,742
5EA	R1	~2.10	1.0	3,387
5AB	C1	.32	1.0	516
	R1	.77	5.0	6,210
	R2	1.64	0.5	1,323
	R3	2.19	5.0	17,662
	R4	5.77	.25	2,327
Subtotal		10.69		28,038

Zone Designation		Acres	Height (ft)	Volume (yd^3)
5A	C1	2.31	.25	932
	C2	3.51	0.5	2,831
	C3	.57	0.5	460
	C4	1.29	1.0	2,081
	C5	7.03	0.5	5,670
	C6	9.74	.25	3,928
	C7	13.27	1.0	21,405
	C8	3.53	0.5	2,847
	C9	2.55	5.0	20,566
	C10	2.89	.25	1,165
	C11	3.78	1.0	6,097
	C12	1.06	5.0	8,549
	C13	2.85	0.5	2,299
	C14	2.25	2.0	7,259
	C15	3.36	2.0	10,839
	C16	.27	5.0	2,178
	C17	2.00	0.5	1,613
	C18	2.69	2.0	8,678
	C19	7.86	.25	3,170
5A	R1	1.43	0.5	1,153
	R2	1.65	.25	665
	R3	2.16	2.0	6,968
	R4	1.56	4.0	10,065
	R5	1.10	1.0	1,774
	R6	.85	3.0	4,113
	R7	1.90	0.5	1,532
	R8	2.30	4.0	14,840
	R10	.97	3.0	4,694
	R11	.53	5.0	4,274
	R12	1.80	5.0	14,517
	R13	1.28	1.5	3,097
	R14	2.10	1.0	3,387
	R15	2.00	0.5	1,613
	R16	1.83	.25	738
	R17	2.50	.25	1,008
	R18	1.01	.25	407
	R19	1.36	.25	548
	SS1	3.35	0.5	2,702
	SS2	3.20	.25	1,290
	Ponds	6.35	-	-
Subtotal		114.04		191,952
D	C1	4.85	5.0	39,115
5DA	R1	2.69	1.0	4,339
5ZA	C1	1.34	12.0	25,937
	R1	.76	1.0	1,226
Subtotal		2.10		27,163

Zone Designation		Acres	Height (ft)	Volume (yd^3)
6A	R1	.66	1.0	1,065
	R2	1.97	.25	794
	R3	1.75	1.0	2,823
	R4	1.36	0.5	1,097
	R5	1.41	1.0	2,274
	R6	1.20	1.0	1,936
	R7	5.71	.25	2,303
	R8	1.93	0.5	1,557
	R9	2.78	2.0	8,968
	C1	.14	1.0	226
	C2	2.06	1.0	3,323
	C3	.73	0.5	589
	C4	.19	0.5	153
	SS1	1.00	.25	403
	Pond	1.69	-	-
Subtotal		24.58		27,511
6B	C1	3.75	1.0	6,049
6C	R1	.23	.25	93
6D	C1	2.10	30 (cone)	33,880
6E	SS1	16.67	.50	13,444
6EA	R1	.15	3.0	726
7A	C1	1.81	5.0	14,598
	C2	7.19	4.0	46,390
	C3	.56	1.0	903
	C4	1.22	1.0	1,968
	C5	2.78	1.0	4,484
	R1	.75	.25	302
	R2	2.63	.25	1,061
	R3	13.85	1.0	22,340
	R4	2.84	1.0	4,581
	R5	4.84	1.5	11,710
	R6	.97	4.0	6,258
	R7	2.03	2.0	6,549
	R8	.89	0.5	718
	R9	5.34	1.0	8,613
	SS1	3.01	.25	1,214
	SS2	.68	0.5	548
	Pond	1.33	-	-
Subtotal		52.72		132,237

Zone Designation		Acres	Height (ft)	Volume (yd^3)
7B	C1	3.48	6.0	33,679
	C2	3.14	15.0	75,972
	C3	7.39	3.0	35,760
	C4	2.68	4.0	17,291
	C5	1.70	3.0	8,226
	R1	4.90	.25	1,976
	R2	1.18	0.5	952
	R3	.88	0.5	710
	R4	3.37	1.0	5,436
	R5	24.00	1.0	38,712
	R6	7.21	1.0	11,630
	SS1	3.15	0.5	2,540
	Pond	1.83	-	-
Subtotal		64.91		232,884
7C	C1	15.71	0.5	12,670
5AA	C1	.21	2.0	677
	R1	1.23	1.0	1,984
	R2	.43	1.0	694
	SS1	1.23	.25	496
	Pond	.09	-	-
Subtotal		3.19		3,851
8A	C1	.33	3.0	1,597
	C2	1.25	1.0	2,016
	C3	5.88	2.0	18,969
	C4	2.48	1.0	4,000
	C5	.01	3.0	48
	C6	3.68	1.0	5,936
	R1	.78	2.0	2,516
	R2	.40	0.5	323
	R3	.53	0.5	427
	R4	.20	4.0	1,290
	R5	.49	2.0	1,581
	S1	.13	2.0	419
	OB1	1.85	5.0	14,920
	OB2	.61	5.0	4,920
	Ponds	.69	-	-
Subtotal		19.31		58,962
8B	C1	7.03	1.0	11,339
	C2	3.61	0.5	2,911
	C3	.31	5.0	2,500
	R1	15.20	0.5	12,259
	R2	1.68	0.5	1,355
	R3	2.69	0.5	2,169
	Ponds	.97	-	-
Subtotal		31.49		32,533

APPENDIX D

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)		L (ft)	W (ft)	Partial Cone	Volumes (cu ft) Wedge	Fill
1	1	85	0.2%	9	31				2283		
1	2	85	0.2%	9	31				2283		
1	3	5411	12.0%	36	125				146093		
1	4	676	1.5%	18	63				18262		
1	5	85	0.2%	9	31				2283		
1	6	85	0.2%	9	31				2283		
1	7	5411	12.0%	36	125				146093		
1	8	85	0.2%	9	31				2283		
1	9	676	1.5%	18	63				18262		
1	10	85	0.2%	9	31				2283		
1	11	85	0.2%	9	31				2283		
1	12	85	0.2%	9	31				2283		
1	13	85	0.2%	9	31				2283		
1	14	85	0.2%	9	31				2283		
1	15	85	0.2%	9	31				2283		
1	16	85	0.2%	9	31				2283		
1	17	85	0.2%	9	31				2283		
1	18	676	1.5%	18	63				18262		
1	19	2283	5.0%	27	94				61633		
1	20	5411	12.0%	36	125				146093		
1		568	1.3%	15	63				15340		
1		3788	8.4%	8	31	x50			102265		
1		3409	7.5%	10	188				92039		
1		568	1.3%	15	63	x10			15340		
1		15278	33.8%	15			1100	50		412500	
	TOTAL	45254 CU YDS									

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)	W (ft)	Partial Volumes (cu ft) Cone	Wedge	Fill
2	1	85	0.2%	9	31			2283		
2	2	85	0.2%	9	31			2283		
2	3	85	0.2%	9	31			2283		
2	4	85	0.2%	9	31			2283		
2	5	85	0.2%	9	31			2283		
2	6	85	0.2%	9	31			2283		
2	7	85	0.2%	9	31			2283		
2	8	85	0.2%	9	31			2283		
2	9	85	0.2%	9	31			2283		
2	10	85	0.2%	9	31			2283		
2	11	85	0.2%	9	31			2283		
2	12	85	0.2%	9	31			2283		
2	13	676	1.7%	18	63			18262		
2	14	676	1.7%	18	63			18262		
2	15	676	1.7%	18	63			18262		
2	16	676	1.7%	18	63			18262		
2	17	676	1.7%	18	63			18262		
2	18	676	1.7%	18	63			18262		
2	19	85	0.2%	9	31			2283		
2	20	85	0.2%	9	31			2283		
2		1023	2.5%	4	94					2761
2		1818	4.5%	4	125					4908
2		18519	45.7%	1		1000	500			50000
2		13889	34.3%	1		750	500			37500

TOTAL 40490 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)	W (ft)	-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
								16107		
3	1	597	2.4%	7	94			8181		
3	2	303	1.2%	8	63			6136		
3	3	227	0.9%	6	63			6136		
3	4	227	0.9%	6	63			6136		
3	5	227	0.9%	6	63			2283		
3	6	85	0.3%	9	31			2283		
3	7	85	0.3%	9	31			2283		
3	8	85	0.3%	9	31			2283		
3	9	85	0.3%	9	31			2283		
3	10	85	0.3%	9	31			2283		
3	11	85	0.3%	9	31			2283		
3	12	85	0.3%	9	31			2283		
3	13	85	0.3%	9	31			2283		
3	14	85	0.3%	9	31			2283		
3	15	85	0.3%	9	31			2283		
3	16	341	1.3%	9	63			9204		
3	17	85	0.3%	9	31			2283		
3	18	85	0.3%	9	31			2283		
3	19	85	0.3%	9	31			2283		
3	20	85	0.3%	9	31			2283		
3		22222	87.7%	1		2000	300			600000

TOTAL 25328 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)		L (ft)	W (ft)	-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
4	1	85	0.6%	9	31				2283		
4	2	85	0.6%	9	31				2283		
4	3	85	0.6%	9	31				2283		
4	4	85	0.6%	9	31				2283		
4	5	85	0.6%	9	31				2283		
4	6	85	0.6%	9	31				2283		
4	7	85	0.6%	9	31				2283		
4	8	85	0.6%	9	31				2283		
4	9	85	0.6%	9	31				2283		
4	10	85	0.6%	9	31				2283		
4	11	85	0.6%	9	31				2283		
4	12	676	5.0%	18	63				18262		
4	13	85	0.6%	9	31				2283		
4	14	85	0.6%	9	31				2283		
4	15	676	5.0%	18	63				18262		
4	16	85	0.6%	9	31				2283		
4	17	85	0.6%	9	31				2283		
4	18	85	0.6%	9	31				2283		
4	19	85	0.6%	9	31				2283		
4	20	42	0.3%	9	31	/2			1141		
4	21	42	0.3%	9	31	/2			1141		
4		3382	25.0%	18	63	x5			91308		
4		7285	53.8%	12	31		1250	25	9284	187500	

TOTAL 13542 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)		W (ft)	-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
									2283		
5	1	85	0.3%	9	31				2283		
5	2	85	0.3%	9	31				18262		
5	3	676	2.7%	18	63				2283		
5	4	85	0.3%	9	31				2283		
5	5	85	0.3%	9	31				2283		
5	6	85	0.3%	9	31				2283		
5	7	85	0.3%	9	31				2283		
5	8	85	0.3%	9	31				18262		
5	9	676	2.7%	18	63				18262		
5	10	676	2.7%	18	63				18262		
5	11	676	2.7%	18	63				2283		
5	12	85	0.3%	9	31				2283		
5	13	85	0.3%	9	31				2283		
5	14	85	0.3%	9	31				2283		
5	15	85	0.3%	9	31				2283		
5	16	85	0.3%	9	31				2283		
5	17	85	0.3%	9	31				2283		
5	18	85	0.3%	9	31				61633		
5	19	2283	9.2%	27	94				18262		
5	20	676	2.7%	18	63				18262	104632	
5		4552	18.3%	18	63		188	63	57068		
5		2114	8.5%	9	31	x25			182617		
5		6764	27.2%	18	63	x10					125000
5		4630	18.6%	1			500	250			

TOTAL 24907 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)	W (ft)	-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
6	1	119	0.4%	10	35			3207		
6	2	75	0.2%	9	30			2020		
6	3	177	0.5%	11	40			4787		
6	4	124	0.4%	8	40			3351		
6	5	485	1.5%	20	50			13090		
6	6	5572	16.9%	15	50	375		9817	140625	
6	7	2094	6.4%	15	120			56549		
6	8	85	0.3%	9	31			2283		
6	9	85	0.3%	9	31			2283		
6	10	85	0.3%	9	31			2283		
6	11	186	0.6%	12	40			5027		
6	12	43	0.1%	7	25			1169		
6	13	178	0.5%	15	35			4811		
6	14	178	0.5%	15	35			4811		
6	15	178	0.5%	15	35			4811		
6	16	31	0.1%	8	20			838		
6	17	178	0.5%	15	35			4811		
6	18	1111	3.4%	3		100	100			30000
6	19	6067	18.5%	54	188 /3			164355		
6	20	6067	18.5%	54	188 /3			164355		
6	21	6067	18.5%	54	188 /3			164355		
6		1268	3.9%	9	31 x15			34241		
6		2424	7.4%	14	50 x7			65450		

TOTAL 32938 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)		W (ft)		-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
										61633		
7	1	2283	2.6%	27	94					2283		
7	2	85	0.1%	9	31					2283		
7	3	85	0.1%	9	31					2283		
7	4	85	0.1%	9	31					18262		
7	5	676	0.8%	18	63					2283		
7	6	85	0.1%	9	31					2283		
7	7	85	0.1%	9	31					2283		
7	8	85	0.1%	9	31					2283		
7	9	85	0.1%	9	31					2283		
7	10	85	0.1%	9	31					2283		
7	11	85	0.1%	9	31					2283		
7	12	85	0.1%	9	31					2283		
7	13	85	0.1%	9	31					2283		
7	14	85	0.1%	9	31					2283		
7	15	85	0.1%	9	31					2283		
7	16	85	0.1%	9	31					2283		
7	17	85	0.1%	9	31					61633		
7	18	2283	2.6%	27	94					18262		
7	19	676	0.8%	18	63					2283		
7	20	85	0.1%	9	31					171203		
7		6341	7.3%	9	31	x75				273925		
7		10145	11.7%	18	63	x15				32070	175000	
7		7669	8.8%	10	35		100	x10				1500000
7		55556	63.9%	1			4000		750			

TOTAL 86982 CU YDS

MINE WASTE VOLUME ESTIMATES FOR CHEROKEE COUNTY KANSAS

Estimated from approximate height, length, width and diameter of waste dumps observed in the field and on aerial photos

SITE	SAMPLE	VOLUME (cu yds)	% TOTAL VOLUME	Height (ft)	Dia. (ft)	L (ft)	W (ft)	-Partial--Volumes-(cu ft)- Cone	Wedge	Fill
								18262		
8	1	676	5.2%	18	63			18262		
8	2	676	5.2%	18	63			9350		
8	3	346	2.6%	14	50			9350		
8	4	346	2.6%	14	50			9350		
8	5	346	2.6%	14	50			9350		
8	6	346	2.6%	14	50			9350		
8	7	346	2.6%	14	50			9350		
8	8	346	2.6%	14	50			9350		
8	9	346	2.6%	14	50			2283		
8	10	85	0.6%	9	31			2283		
8	11	85	0.6%	9	31			2283		
8	12	85	0.6%	9	31			2283		
8	13	85	0.6%	9	31			2283		
8	14	85	0.6%	9	31			2283		
8	15	85	0.6%	9	31			1636	18750	
8	16	755	5.8%	10	25	150		18262		
8	17	676	5.2%	18	63			18262		
8	18	676	5.2%	18	63			9350	53571	
8	19	2330	17.8%	14	50	150		3207		
8	20	119	0.9%	10	35			22827		
8		845	6.5%	9	31 x10			91300		
8		3382	25.9%	18	63 x5					

TOTAL 13068 CU YDS

APPENDIX E

COMPARISON OF PILE VOLUMES

Location Number	CH_2M Hill Volume (ft^3)	G. Andes Volume (ft^3)
2-3	2,283	14,079
3-1	16,107	24,960
3-2	8,181	6,739
3-3	6,136	7,372
3-5	6,136	148,078
3-6	2,283	5,158
3-7	2,283	40,562
3-8	2,283	50,965
3-11	2,283	103,915
3-12	2,283	70,200
3-13	2,283	28,431
3-16	9,204	97,998
3-17	2,283	36,055
3-20	2,283	11,271
4-10	2,283	14,759
4-11	2,283	11,310
4-12	18,262	99,688
4-13	2,283	60,937
4-14	2,283	7,582
8-3	9,350	11,243
8-6	9,350	9,370
8-7	9,350	20,631
8-8	9,350	14,438
8-9	9,350	24,375
8-10	2,283	4,424
8-15	2,283	13,120
8-16	20,386	277,300
8-18	18,262	61,893
1-4	18,262	450
1-7	146,093	180,000
1-16	2,283	7,023
1-17	2,283	17,230
2-1	2,283	26,957
2-2	2,283	2,986
2-4	2,283	8,485
2-6	2,283	9,370
2-7	2,283	13,130
2-8	2,283	5,852
2-9	2,283	55,814
2-12	2,283	11,846
2-15	18,262	16,433
2-19	2,283	8,226
1-18	18,262	10,618
6-4	3,351	17,342
6-1	3,207	2,633

Location Number		CH_2M Hill Volume (ft^3)	G. Andes Volume (ft^3)	
6-5		13,090	1,877	
6-6		9,817	7,108	
6-12		1,169	3,775	
6-13		4,811	9,984	
5-10		18,262	15,000	
5-6		2,283	609	
7-8		2,283	7,256	
7-17		2,283	8,200	
1-2		2,283	26,364	
	TOTAL	472,500	1,751,421	371% Increase

54 out of 160 points
Andes + 45
Andes - 9